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the
**Large**
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## Interface Specification

# LBRB CRYO-ASSEMBLIES – D4 DIPOLES


***Abstract***

The superconducting D4 magnet consists of an LBRB cryo-assembly containing an MBRB magnet. Two LBRB cryo-assemblies, plus one spare, will be built. The installation locations are IR4L and IR4R. This document specifies the interfaces of the LBRB cryo-assemblies to the MQY(Q5) quadrupole, the QRL cryogenic transfer line, the CERN provided beam screen and warm-to-cold transition, support jacks, and alignment systems.



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## *History of Changes*

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# 1. INTRODUCTION

Each superconducting D4 dipole cryo-assembly (LBRB) will be a dual aperture, RHIC-type coil in single cold mass [1,2,3]. The D4 magnets, along with D3 magnets, are used at IR4 to increase the separation of the beams of the LHC from the nominal spacing of 194 mm to 420 mm so that individual RF cavities can be installed for each beam. The beams are then returned to the nominal 194 mm spacing [1].

The D4 magnet is a two-in-one magnet, having two coils in one cold mass similar to the LHC arc magnets [2]. The D4 cold mass has an elliptical cross section with dimensions similar to that of an LHC arc magnet [3].

One D4 magnet (MBRB) is located on each side of IP 4, plus one spare is to be built. One side the region is shown in Figure 1. D4 magnets operate at 4.5K in two-phase helium.

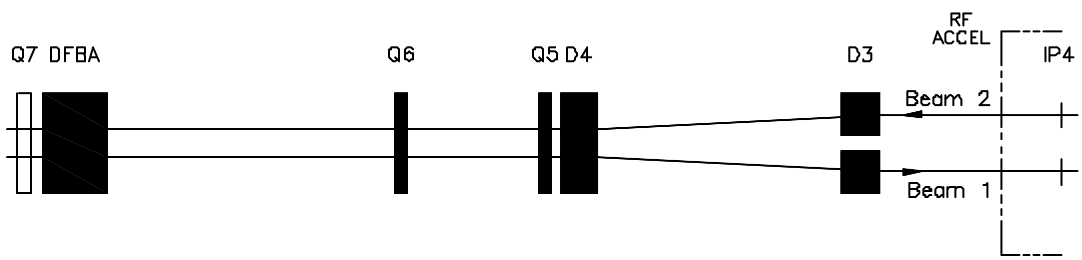



***Figure 1 Layout of D3 and D4 in the left side of Intersection Region 4. D3 and D4 change the beam separation from 194 mm to 420 mm.***

The configurations of the two D4 cryo-assemblies are identical, with the exception of the QQS attached to D4 (addressed later in section 5.1). Magnet D4 and the adjacent CERN-built magnet Q5 are connected together to form a cryogenic module. The operation and instrumentation specific to D4 takes this into account. One spare is built to replace either of the two installed units.

# 2. GENERAL SPECIFICATIONS

The LBRB cryo-assembly uses two collared coils in one steel yoke contained in a stainless steel shell (2-in-1 cold mass). The yoke is slightly wider than it is high, giving an oblate shape to the cold mass. There is one such cold mass in an LBRB cryo-assembly. The cryostat for D4 is 914mm (36 in) in diameter, the same as the LHC arc dipole. Table 1 contains a summary of the LBRB parameters.

***Table 1 Specifications of the LBRB Cryo-assemblies***

| ***Item*** | ***Value*** |
|---|---|
| Quantity + (Spares) | 2 + (1) |
| Operating Temperature | 4.5 K |
| Cold Bore Tube[4] OD / ID | 73 / 69 mm |
| Beam Dynamic Heat Load | Active Beam Screen |
| Coil Prestress Application | Collar |
| Cold Mass Design | 2 in 1 |
| Bore Spacing (cold) | 194 mm |
| Yoke Size | 550 mm x 625 mm |
| Shell Thickness | 9.5 mm (0.375 in) |
| End Plate Thickness | 70 mm (2.75 in) |
| Cold Mass Length (endplate – endplate) | 9.814 m (386.4 in) |
| Cold Mass Length (end volume – end volume) | 10.400 m (409.4 in) |
| Cold Mass per Cryostat | 1 |
| Cryostat Length (incl QQS) | 10.278 m (404.6 in) |
| Cryostat Diameter | 914 mm (36 in) |

# 3. GENERAL LAYOUT

## 3.1 CRYO-ASSEMBLY CROSS SECTION

The LBRB (D4) cryo-assembly cross section at a support post location, as viewed from the lead end, is shown in Figure 2.

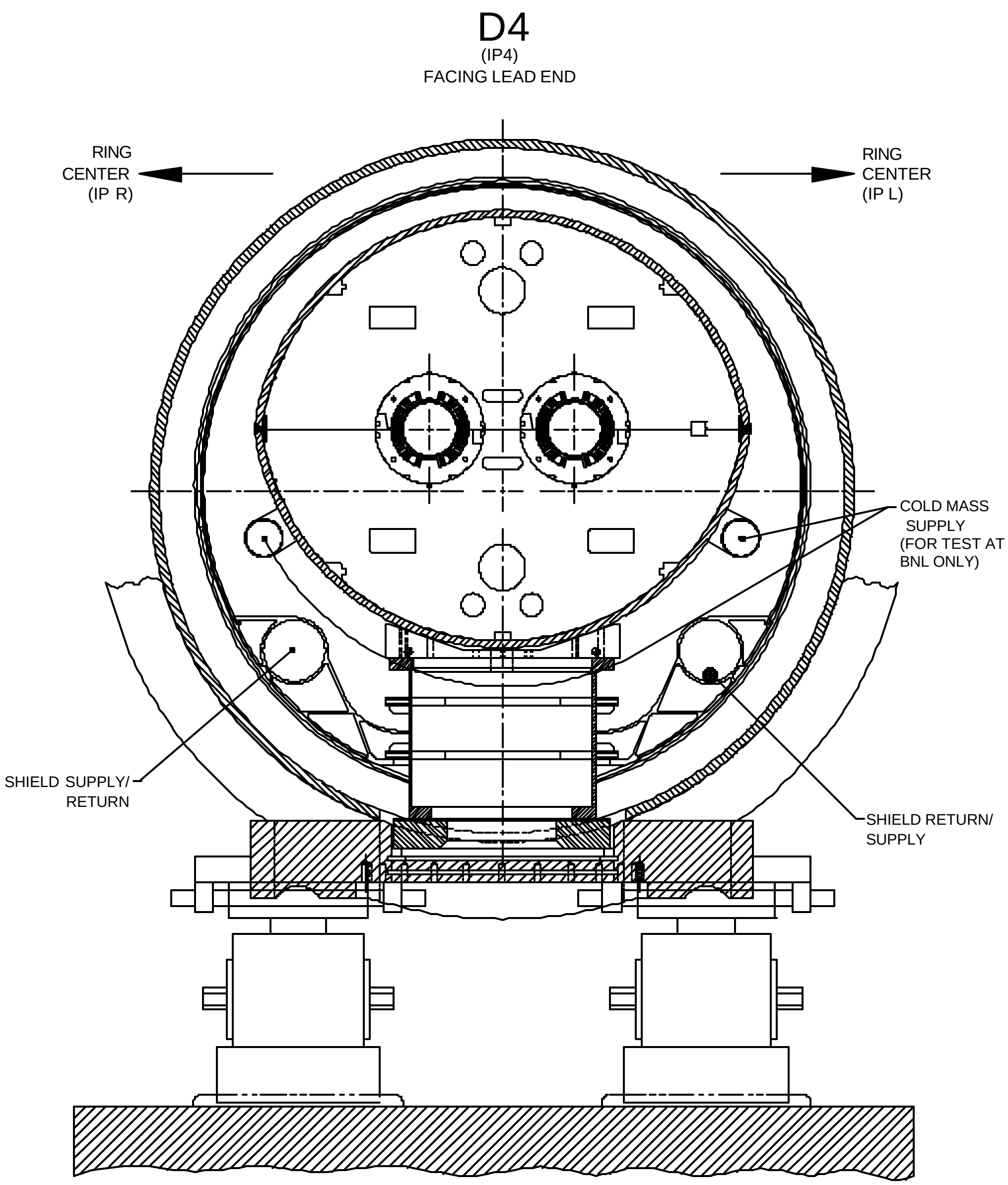



***Figure 2 Cross Section of the D4 (LBRB) Cryo-assembly at a support post location, viewed from the lead end of the magnet.***

## 3.2 LOCAL COORDINATE SYSTEM

Figure 3 shows the LBRB local coordinate system which is similar to the LHC standard for local coordinate systems [5] except that the origin is always located at the lead end for each D4. The XZ plane (Y=0) is coincident with the restraint flats welded to the dome and referenced in specification LHC-LI-ES-0001 [6] and is centered between the two cold bore tubes. Positive X always points toward the LHC ring center.

The coordinate system is defined in the same way for both warm and cold conditions, i.e. it is fixed on the lead end of the cold mass. This results in a displacement of the coordinate system due to thermal contraction of the cold mass. The cold origin is displaced 0.8 mm in the negative Z-direction (down) with respect to the warm position. It is displaced 16 mm in the positive Y-direction for a magnet on the left side of the IP and 16 mm in the negative Y-direction for a magnet on the right side.

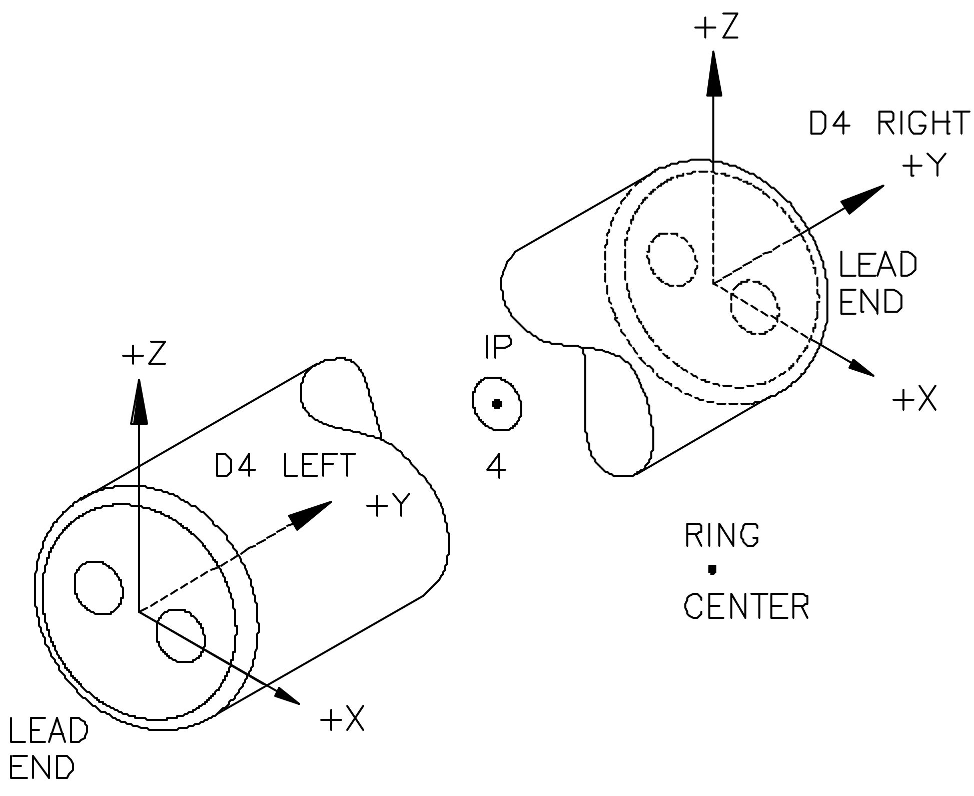



***Figure 3 Local coordinate system for LBRB. The flat surface shown at the lead end is schematic only; it represents interconnect planes "L/C" as defined by the restraint flats welded to the dome and referenced in specification LHC-LI-ES-0001. [6]***

## 3.3 PIPING

Figure 4 shows transverse and longitudinal views of the lead end of the magnet and cryostat. Lower case letters are used to label the pipes and tubes that BNL has designed into the system, and these letters correspond (where applicable) to the header pipes, labelled in upper case letters on the CERN cryogenic flow diagrams, to which the magnet piping eventually connects. These sections also show the tubing stubs protruding from the end volumes of the cold mass. Tubing stubs are needed to admit liquid helium, vent gaseous helium, and convey buses through liquid helium to the source of electrical power. The details of the cooling system are described in [7].

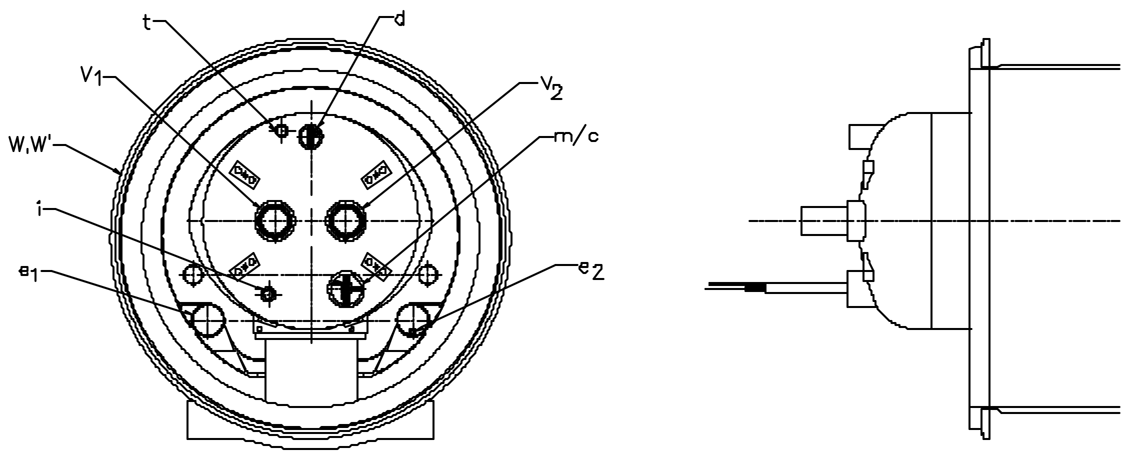



***Figure 4 Cryogenic connections at the lead end volume***

Coming out of the cold mass end volumes there are five tubing stubs, three at the lead end (m/c, d and i), and two at the non-lead end (CL, and LD). There is also an additional stub at the lead end labelled t used only for cold testing at BNL; it will be capped before the magnet is shipped to CERN. The lead end stubs emanate from the domed face of the end volume. The non-lead end stubs connect to the cylindrical portion of the end volume at the top.

Stubs labelled CL are used to admit liquid helium into the cold mass either in cooldown mode or steady state mode. Stubs labelled d and LD are used as vents to return helium gas, collected in the top of the end volume, to the cryogenic system, sometimes via Q5. The m/c stub at the lead end provides a tube for the D4 powering bus to connect to a bus in Q5 as well as for the liquid helium in the two adjacent magnets to freely communicate during fill and steady state conditions.

The i stub is provided for the instrumentation leads to exit the end volume. An instrumentation feedthrough system (IFS) is attached by BNL to the i stub; CERN does not interface to it directly. The IFS is described in more detail in section 4.2.

Shown within the cryostat are the shield supply and return pipes labelled $e_1$ and $e_2$. Pipe $e_1$ is the shield pipe which is an integral part of the CERN-supplied heat shield extrusion and is therefore thermally connected to the shield. Pipe $e_2$ is a stainless steel line inserted within the shield and intentionally thermally isolated somewhat from it to prevent cooling instability. Cooling gas can enter either $e_1$ or $e_2$ first, and return through the other, without affecting shield function.

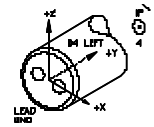
# 4. LBRB – MQY(Q5) INTERFACES

The lead end of the cold mass always faces away from the IP and connects to the CERN-supplied Q5 magnet. The D4-Q5 cryogenic pair is "turned" as a unit for left side and right side of the IP installations. Therefore all interconnects between the pair remain unchanged.

## 4.1 TUBE COORDINATES

Since the D4-Q5 pair is rotated from one side of the IP to the other and directions of the axes in the local coordinate systems are the same on both sides of the IP, the signs of the coordinate positions of the tubes change in many cases. The sizes of the various tubing stubs for the D4 magnet and their warm coordinate positions on the left and right sides of the IP are shown in Tables 2 and 3 respectively. Welding and cutting clearances have been taken into account in positioning these tubes so that there exist 50 mm radial and 60 mm axial clearance envelopes around each pipe.

***Table 2 Warm coordinate positions for the D4 lead end on the left side of the IP. Most pipes are in standard US sizes with transitions to terminate at the interface in standard metric sizes.***




| Name | Description | OD x Wall Tube (mm) | Warm Coordinates X (mm) | | Z (mm) | | Y (mm) | |
|---|---|---|---|---|---|---|---|---|
| V1 | Cold bore tube, left aperture | 73 x 1.9 | -97.2 | ±1 | 0.0 | ±1 | -60.0 | ±2 |
| V2 | Cold bore tube, right aperture | 73 x 1.9 | 97.2 | ±1 | 0.0 | ±1 | -60.0 | ±2 |
| d | Helium gas vent | 50.8 x 2.1<br>102.0 x 1.65[a] | 0.0 | ±2 | 222.0 | ±2 | -90.0 | ±2 |
| m/c | Bus/helium | 63.5 x 1.65<br>102.0 x 1.65[a] | 111.0 | ±1 | -193.0 | ±1 | -90.0 | ±2 |
| i | Instrumentation | BNL interface only | -111.0 | ±2 | -193.0 | ±2 | -90.0 | ±2 |
| $e_1$ | Heat shield sup/ret (connected) | 17.2 x 1.0<br>87.0 x 3.5[b] | -270.0 | ±2 | -290.0 | ±2 | 56.0 | ±2 |
| $e_2$ | Heat shield ret/sup (isolated) | 17.2 x 1.0<br>19.0 x 1.65[b] | 270.0 | ±2 | -320.5 | ±2 | 56.0 | ±2 |
| t | Helium supply (BNL test only) | Capped | -105.6 | ±2 | 226.3 | ±2 | -40.0 | ±2 |
| W | Cryostat (rotatable flange) | 1055 x 61.5 | 0.0 | ±3 | -80.0 | ±3 | 329.0 | ±3 |
| W' | Cryostat (flange mount) | 1008 x 59.0 | 0.0 | ±3 | -80.0 | ±3 | 299.0 | ±3 |

Note a: Dimensions of flanges welded to tubes. The flanges, when they are present, are located at the interface.

Note b: Dimensions of tube behind interface. A transition section is used to reach the interface dimension of 17.2 x 1.0.

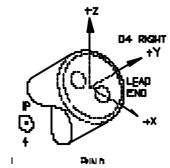



***Table 3 Warm coordinate positions for the D4 lead end on the right side of IP. Most pipes are in standard US sizes with transitions that terminate at the interface in standard metric sizes.***

| Name | Description | OD x Wall Tube (mm) | Warm Coordinates X (mm) | | Z (mm) | | Y (mm) | |
|---|---|---|---|---|---|---|---|---|
| V1 | Cold bore tube, left aperture | 73 x 1.9 | 97.2 | ±1 | 0.0 | ±1 | 60.0 | ±2 |
| V2 | Cold bore tube, right aperture | 73 x 1.9 | -97.2 | ±1 | 0.0 | ±1 | 60.0 | ±2 |
| d | Helium gas vent | 50.8 x 2.1<br>102.0 x 1.65[a] | 0.0 | ±2 | 222.0 | ±2 | 90.0 | ±2 |
| m/c | Bus/helium | 63.5 x 1.65<br>102.0 x 1.65[a] | -111.0 | ±2 | -193.0 | ±2 | 90.0 | ±2 |
| i | Instrumentation | BNL interface only | 111.0 | ±2 | -193.0 | ±2 | 90.0 | ±2 |
| $e_1$ | Heat shield sup/ret (connected) | 17.2 x 1.0<br>87.0 x 3.5[b] | 270.0 | ±2 | -290.0 | ±2 | -56.0 | ±2 |
| $e_2$ | Heat shield ret/sup (isolated) | 17.2 x 1.0<br>19.0 x 1.65[b] | -270.0 | ±2 | -320.5 | ±2 | -56.0 | ±2 |
| t | Helium supply (BNL test only) | Capped | 105.6 | ±2 | 226.3 | ±2 | 40.0 | ±2 |
| W | Cryostat (rotatable flange) | 1055 x 61.5 | 0.0 | ±3 | -80.0 | ±3 | -329.0 | ±3 |
| W' | Cryostat (flange mount) | 1008 x 59.0 | 0.0 | ±3 | -80.0 | ±3 | -299.0 | ±3 |

Note a: Dimensions of flanges welded to tubes. The flanges, when they are present, are located at the interface.

Note b: Dimensions of tube behind interface. A transition section is used to reach the interface dimension of 17.2 x 1.0.

All of the tubes move due to cooldown from 300 K to 4.3 K. The changes in position are expressed as a combination of two movements. One movement is that of the origin of the coordinate system, Figure 3. which is centered between the two beam tubes and moves down due to the shrinkage of the cold mass and the support posts. The origin is displaced 0.8 mm in the negative Z-direction (downward) and 16 mm toward the center of the magnet in the Y-direction upon cooldown. The movements of pipes and the cold mass reflect the fact that all are fixed to the cryostat at the longitudinal midpoint, unless otherwise stated.

The other movement of each tube is with respect to the origin. That movement is described in Table 4 for each tube. Tubes V1, V2, d, and m/c all move in a similar manner due to the shrinkage of stainless steel and their movements are expressed as a percentage of their distance from the origin. Heat shield tubes $e_1$ and $e_2$ move due to a combination of material shrinkages and their movements are expressed as explicit distances toward (or away from) the origin.

***Table 4 Cold changes in position at the D4 lead end on both sides of the IP. The origin has been displaced 0.8 mm in the negative Z-direction and 16 mm toward the center of the magnet in the Y-direction upon cooldown. All pipes and the cold mass are fixed to the cryostat at the longitudinal midpoint, unless otherwise stated.***

| Name | Description | Change in Position With Respect to the Origin |
|---|---|---|
| V1 | Cold bore tube, left aperture | X: moves 0.3% toward origin. |
| V2 | Cold bore tube, right aperture | Z: moves 0.3% toward origin. |
| d | Helium gas vent | Y: moves 0.3% toward origin. |
| m/c | Bus/helium | |
| $e_1$ | Heat shield sup/ret (connected) | X: moves 0.4% (1.1 mm) toward origin.<br>Z: moves 0.2 mm toward origin.<br>Y: moves 4 mm away from origin. (Net movement is 20 mm toward cold mass center.) |
| $e_2$ | Heat shield ret/sup (isolated) | X: moves 1.1 mm toward origin.<br>Z: moves 0.2 mm toward origin.<br>Y: moves 6 mm toward origin. (Net movement is 10 mm toward cold mass center.) |

## 4.2 ELECTRICAL CONNECTIONS

Figure 5 is a schematic diagram of the main power to the D4 magnet coils. Labelling of the terminals follows the convention specified in [8].

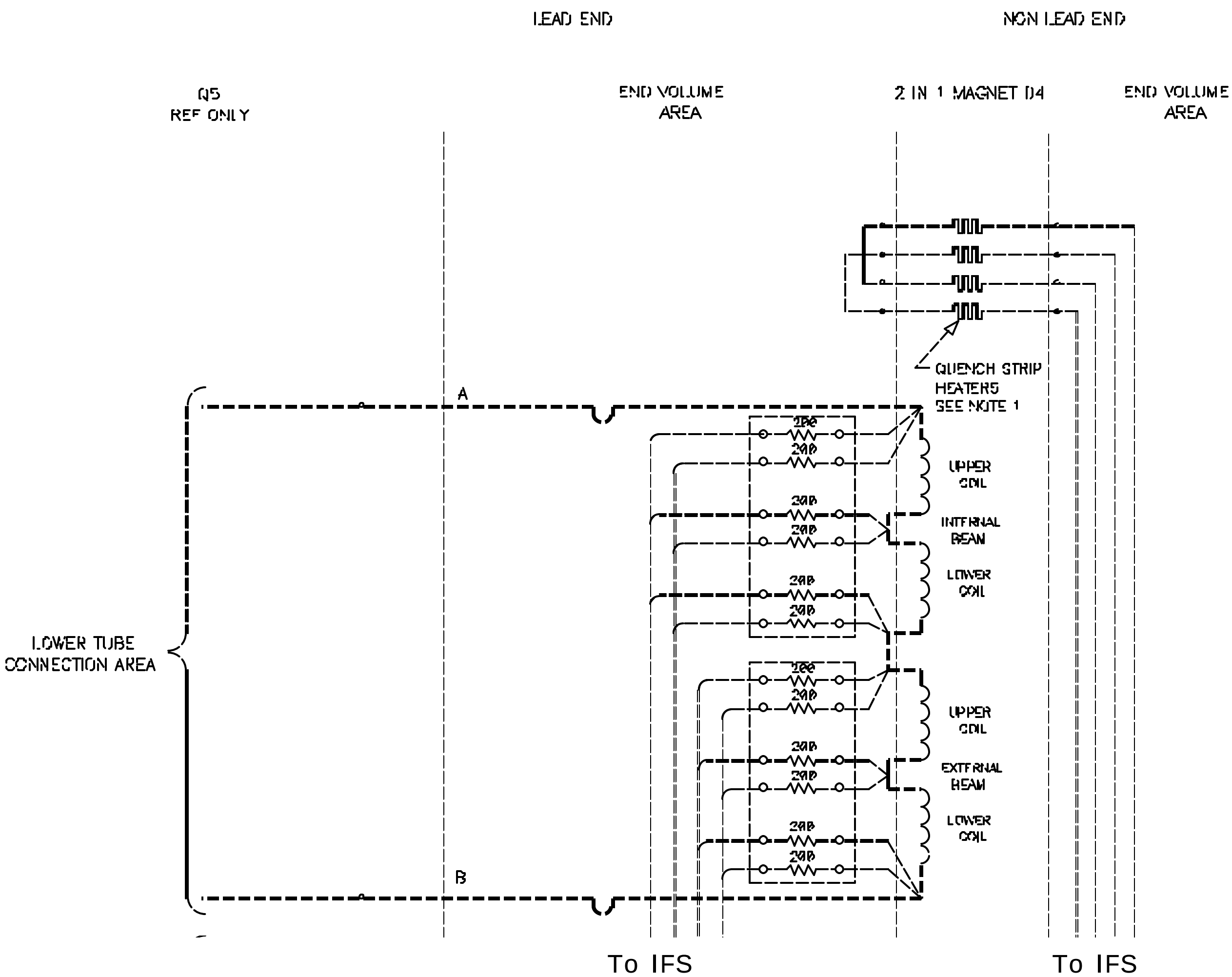



***Figure 5. Electrical Schematic of Power Leads for the D4 Magnet.***

Figure 6 is a schematic diagram of the instrumentation from the cold mass to the instrumentation feed through system (IFS).

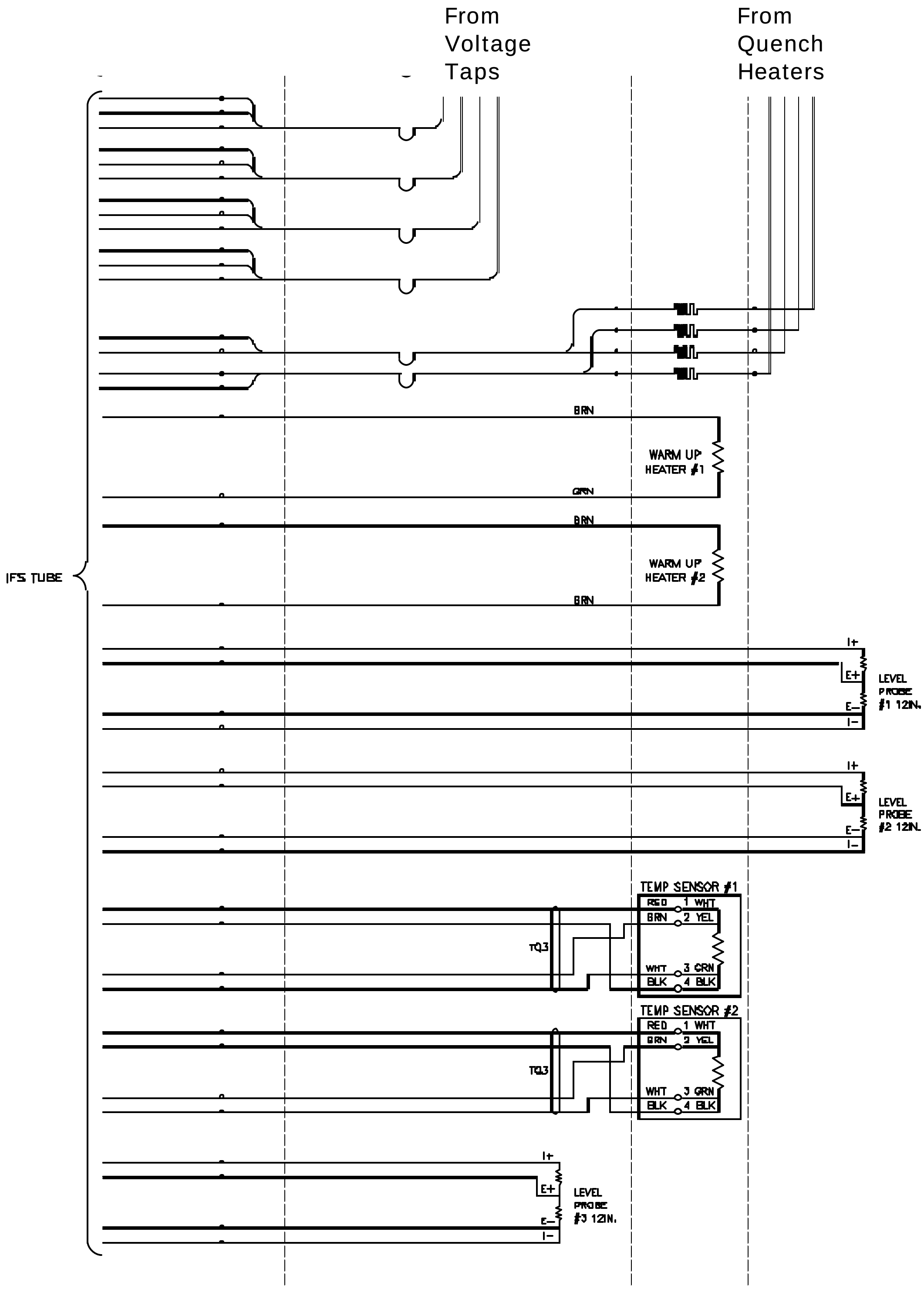



***Figure 6 Electrical Schematic for the Instrumentation Feedthrough System (IFS)***

A bus/flex joint assembly of BNL design will be used in the lead end volume to accommodate expansion and contraction of the short powering bus connected to the Q5 through-bus (Figure 7). The electro-mechanical design inside the end volume will connect the two collared coils in series to the bus/flex joint assembly (see Figure 5).

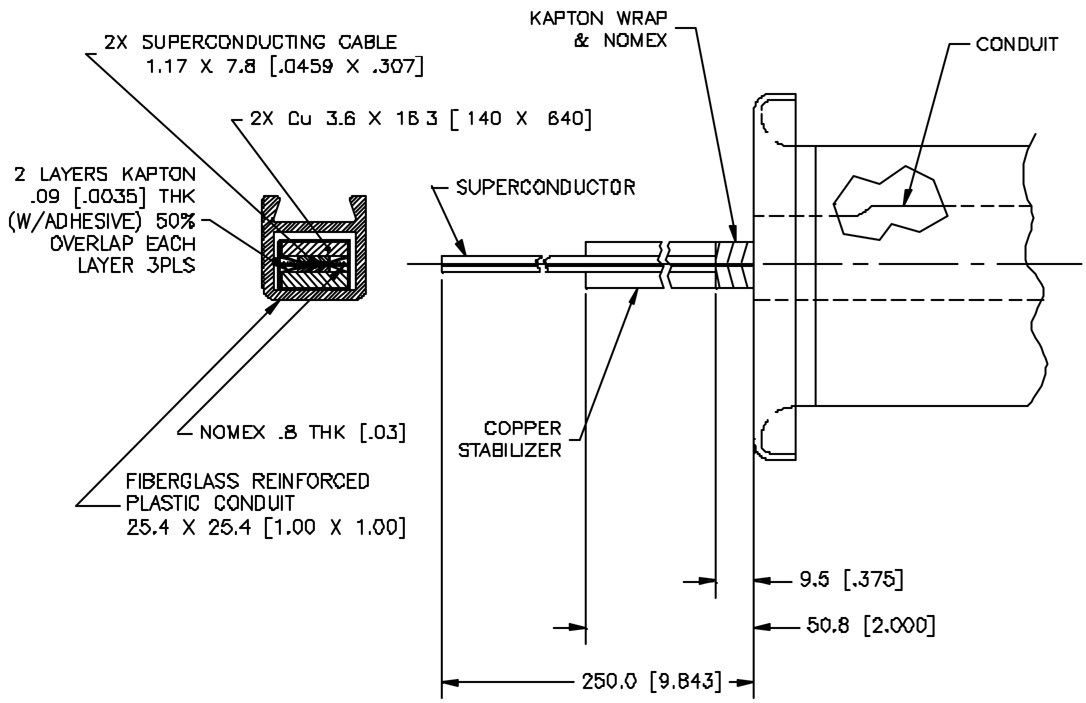



***Figure 7. Busbar interface at m/c bus exit. Flex joint in neutral position. Dimensions are given in mm [inches].***

Instrumentation supplied in D4 is shown in Table 5. All instrumentation and control wiring is routed along and lashed to the flex joint, with expansion loops between terminations and the flex joint lash point to provide for differential thermal contraction internal to the magnet.

***Table 5 Instrumentation and control wiring exiting the cold mass through the i stub. The external lengths are measured from the IFS (Figure 8).***

| Lead | Length | Description |
|---|---|---|
| Temperature sensors | 300 mm | 2 twisted quads (total 8 wires, #32 AWG.) |
| Voltage taps | 300 mm | 4 cables (3-#28 AWG wires each) |
| | | red = "A" coil lead |
| | | black = "B" coil lead |
| | | yellow = upper/lower coil crossover joint |
| Quench heaters | 300 mm | 4 wires, #22 AWG |
| Warm-up heater | 300 mm | 2 twisted pairs (total 4 wires, #26 AWG.) |
| Liquid Level Sensors | 300 mm | 3 twisted quads (total 12 wires, #32 AWG.) |

There are two temperature sensors located within the cold mass on the outside of the yoke near the longitudinal center. One of these sensors is redundant. Temperature sensors are the short type thermometer assemblies (36 mm x 12 mm x 4.2 mm) typically used by CERN [9]. The sensors are calibrated and supplied to BNL by CERN.

The 3-wire voltage tap cables consist of three Tefzel-over-Kapton insulated wires within an outer helical wrap of 0.04 mm thick Kapton. The voltage tap leads are soldered to the "A" and "B" leads, to the coil lead splice between apertures, and to the crossover splice between upper and lower coils for each aperture, as close as possible to the lead end of the coils. Tefzel is used only as a convenience for color coding and Kapton retention; no credit is taken for insulating properties.

The quench protection heater leads power the heaters in two independent circuits to create a level of redundancy in case of failure in one circuit. Two yoke warm-up heaters are located within the lead end volume.

All D4 magnets have helium level sensors provided in the non-lead end volume which are used to control cryogenic operation of the D4-Q5 pair. Two sensors are provided for redundancy. Where the D4 is lower than the Q5 the level sensors in D4 are not used, that function being controlled by the sensors in Q5. A level third sensor is at the lead end and is only needed during operation of the magnet on the test stand at BNL. The leads for this sensor must be terminated to prevent shorts and are included in Table 5, but they are not active.

The wiring exits the end volume through the i stub into the IFS (instrument feedthrough system), separating from the main power buswork on the flex joint within the end volume. The IFS is a copy of the CERN design to the extent possible. It exits the cryostat in the standard way (see Figure 8), but there are notable exceptions: the stainless tube from the cold mass to the thermalisation point is larger in diameter, there is a flex hose section above the thermalisation point to accommodate cold mass insertion into the vacuum vessel, and the 40-pin feedthrough plate is attached by CERN after magnet shipment. A short section of tube, 206 mm OD x 2 mm wall thickness, is added to the top of the standard flange. The tube terminates 51 mm above the joint between the tube and flange in the vacuum vessel wall. The centerline of the flange is located at the top center line of the vacuum vessel and 910 mm back from the lead end flange. At least 300 mm of instrumentation wire length will be available for connection to the 40-pin feedthrough plate.

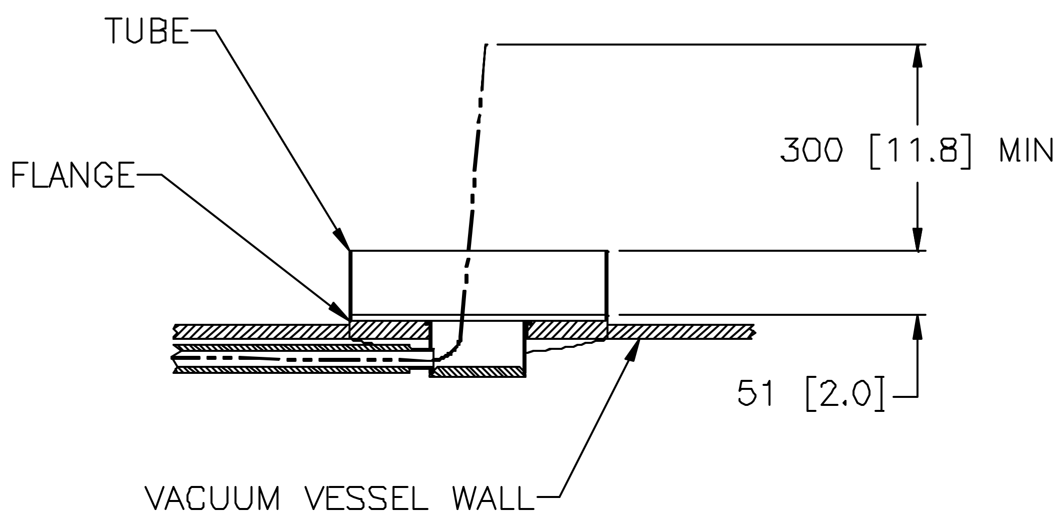



***Figure 8. IFS flange on the vacuum vessel. Dimensions are in mm [inches]. A tube of 206 mm OD and 2 mm wall thickness extends 51 mm above the tube-flange joint.***

## 5. LBRB – QRL INTERFACE

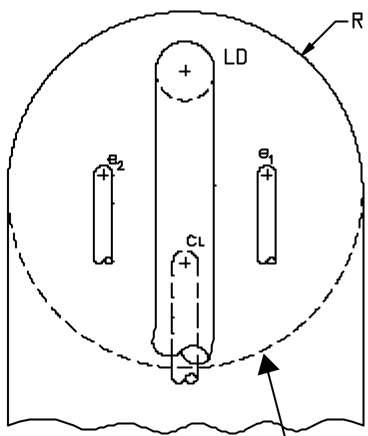
A QQS service module is connected to the non-lead end of D4. Helium for the D4-Q5 cryogenic module is supplied and returned through this QQS and another at the far end of Q5. A left side D4-Q5 module is essentially "turned" end for end to make a right side pair. However, the QRL cryogenic transfer line, to which the QQS attaches, is always located toward the outside of the tunnel. The impact on the D4 design is that there must be one D4 magnet built with a left-facing QQS, and another with a right-facing QQS. However, the positions and functions of the pipes at the interface to the QRL will be identical for both types as viewed from the ring center. This is accomplished through internal plumbing changes unique to each type which provide the correct interface arrangement.

BNL is responsible for integrating the QQS into the construction of the D4 magnet. The D4 cryostat will therefore include an extension and riser for the exiting QQS piping. The shipped length of the resulting magnet assembly will be less than 10.7 m to allow shipment inside a standard 40 ft container. The cryostat will have mechanical seals at both ends.

Since the spare magnet must be capable of being installed in either left or right sides, its QQS is shipped as a partially complete assembly plus a kit of parts. When a spare is needed, CERN will complete the QQS for that specific ring location using the parts provided.

## 5.1 INTERFACE PLANES

The configuration of the QQS internal plumbing is shown in Figure 9. The positions of the pipes at the interface to the QRL are defined with respect to Plane Q as defined in Figure 9. As with the main local coordinate system defined in section 3.2 (plane “C” in Figure 9), the Y-axis is in the clockwise beam direction, the X-axis points towards the center of the ring, and the Z-axis completes the right-hand coordinate system. At room temperature the origin of the “Q” coordinate system is translated from that of the “C” coordinate system +684.5 mm in Z, 0 mm in X, and +10315 mm in Y (left side of the IP) or –10315 mm in Y (right side of the IP).




The interface to the QRL is identical for both left and right magnets as viewed from the ring center. The origin of Plane Q is defined such that the "z" positions of $e_1$ & $e_2$ remain on the horizontal centerline of the origin after cooldown.

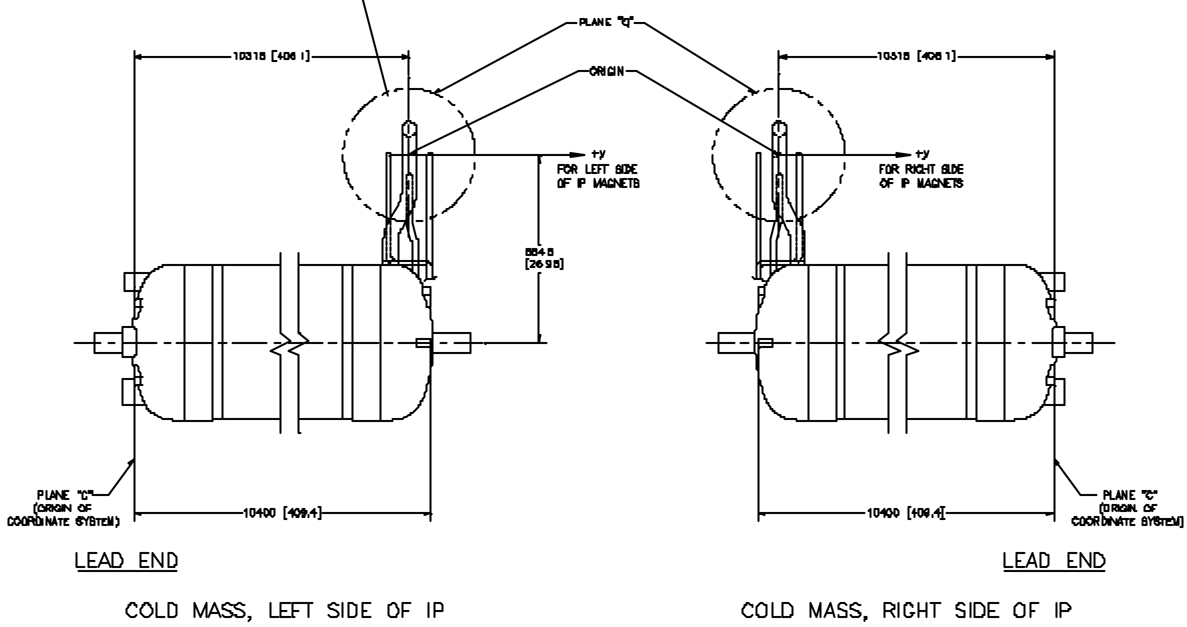



***Figure 9 Interface Planes “Q” and “C” viewed from inside the ring. The warm dimensions in mm [inches] are shown. “X” is positive out of the page.***

## 5.2 TUBE POSITIONS

The sizes of the various tubes for the QQS and their warm coordinate positions are shown in Table 6. The QQS has been designed so the tube positions are the same on both sides on the IP. Their movements in position due to cooldown are shown in Table 7.

***Table 6 Warm coordinate positions of pipes at the QQS-QRL interface on both sides of the IP. Positions are expressed with respect to interface plane "Q" as defined in Figure 9.***

| **Name** | **Description** | ***OD x Wall Tube (mm)*** | ***Warm Coordinates X (mm)*** | | ***Z (mm)*** | | ***Y (mm)*** | |
|---|---|---|---|---|---|---|---|---|
| LD | Helium gas vent | 64.0 x 2.0[a]<br>50.8 x 1.65[b] | -301.0 | ±2 | 95.0 | ±2 | 0.0 | ±2 |
| CL | Helium supply | 64.0 x 2.0[a]<br>25.4 x 1.65[b] | -367.0 | ±2 | -80.0 | ±2 | 0.0 | ±2 |
| $e_1$ | Heat shield sup/ret (connected) | 17.2 x 1.0 | -367.0 | ±2 | 0.0 | ±2 | 75.0 | ±2 |
| $e_2$ | Heat shield ret/sup (isolated) | 17.2 x 1.0 | -367.0 | ±2 | 0.0 | ±2 | -75.0 | ±2 |
| R | QQS vacuum enclosure | 380.0 x 26.5[a]<br>335.0 x 4.0[b] | -223.0 | ±2 | 0.0 | ±2 | 0.0 | ±2 |
| S | QQS heat shield | 277.0 X 2.0 | -253.0 | ±2 | 0.0 | ±2 | 0.0 | ±2 |

Note a: Dimensions of flange welded to tube.

Note b: Dimensions of tube behind flange or transition.

***Table 7 Cold changes in position of pipes at the QQS-QRL interface on the both sides of the IP. The origin of plane "Q" has been displaced 2.0 mm in the negative Z-direction (down) and 16 mm in the Y-direction (toward the magnet center) upon cooldown with respect to the magnet center.***

| *Name* | *Description* | *Changes* |
|---|---|---|
| LD<br>CL<br>$e_1$ | Helium gas vent<br>Helium supply<br>Heat shield sup/ret (connected) | X: moves 1 mm toward origin (cold mass center)<br>Z: no movement within coordinate system, origin moves 2 mm toward cold mass center<br>Y: no movement within coordinate system, origin moves 16 mm toward cold mass center |
| $e_2$ | Heat shield ret/sup (isolated) | X: moves 1 mm toward origin (cold mass center)<br>Z: no movement within coordinate system, origin moves 2 mm toward cold mass center<br>Y: moves 5 mm away from origin, origin moves 16 mm toward cold mass center, net movement is 21 mm toward cold mass center |
| S | QQS heat shield | X: moves 1 mm toward origin (cold mass center)<br>Z: moves 1 mm down within coordinate system, origin moves 2 mm toward cold mass center<br>Y: no net movement, heat shield moves 16 mm away from cold mass center within coordinate system, origin moves 16 mm toward cold mass center |

# 6. LBRB – NON-LEAD END INTERFACES

Installation connections needed at the non-lead end are the cold bore tube, the beam screen, the warm-to-cold transition, and the heat shield, MLI blankets, and cryostat.

## 6.1 COLD BORE TUBE, BEAM SCREEN AND WARM-TO-COLD TRANSITION

CERN will design and provide beam screens and warm-to-cold transitions (WCT), one of each per bore. They will be installed after the magnet arrives at CERN. The spaces indicated in Figure 10 are reserved for the cold bore – beam screen interface (#1 in Figure 10), WCT – heat shield interface (#2), and WCT – vacuum closure interface (#3) are shown.

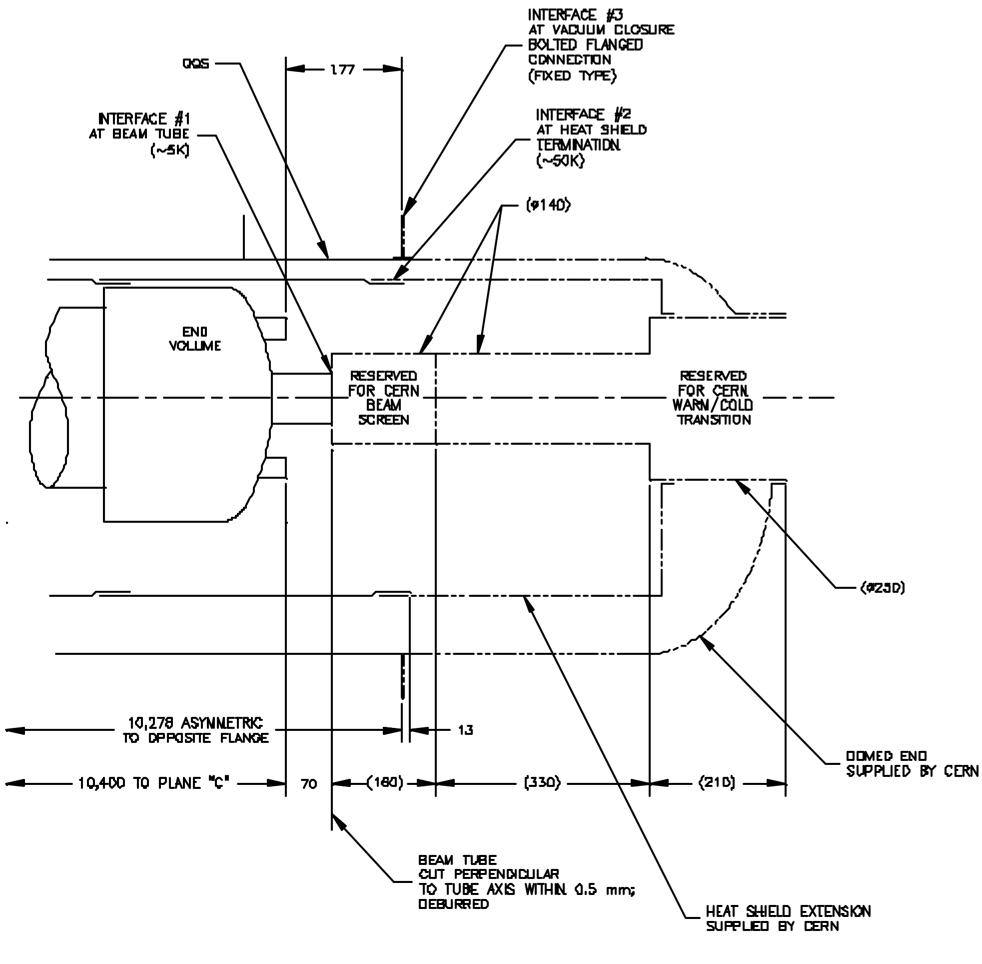



***Figure 10  Reserved space for the beam screen interface and warm-to-cold transition.***

## 6.2 TUBE POSITIONS

The warm coordinate positions and tubing diameters of the cold bore tubes and cryostat vacuum flange are given for the left and right sides of the IP in Tables 8 and 9 respectively. The cold Y-coordinate positions are also shown. The cold X- and Z-cold coordinate positions are the same as for the lead end (Tables 2 and 3). The local coordinate system, which is referenced to the lead end volume moves with cooldown as described in Section 3.2.

***Table 8 Coordinate Positions for the D4 non-lead end on the left side of the IP.***

| Name | Description | OD x Wall Tube (mm) | Coordinate Positions X (mm) | | Z (mm) | | Warm Y (mm) | | Cold Y (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| V1 | Cold bore tube, left aperture[a] | 73 x 1.9 | -97.2 | ±1 | 0.0 | ±1 | 10470 | ±3 | 10438 | ±3 |
| V2 | Cold bore tube, right aperture[a] | 73 x 1.9 | 97.2 | ±1 | 0.0 | ±1 | 10470 | ±3 | 10438 | ±3 |
| W | Cryostat (fixed flange beyond QQS) | 1055 x 82.5 | 0.0 | ±3 | -80.0 | ±3 | 10577 | ±3 | 10561 | ±3 |

Note a: “Left” and “right” are defined as viewed from lead end.

***Table 9 Coordinate Positions for the D4 non-lead end on the right side of the IP.***

| Name | Description | OD x Wall Tube (mm) | Coordinate Positions X (mm) | | Z (mm) | | Warm Y (mm) | | Cold Y (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| V1 | Cold bore tube, left aperture[a] | 73 x 1.9 | 97.2 | ±1 | 0.0 | ±1 | -10470 | ±3 | -10438 | ±3 |
| V2 | Cold bore tube, right aperture[a] | 73 x 1.9 | -97.2 | ±1 | 0.0 | ±1 | -10470 | ±3 | -10438 | ±3 |
| W | Cryostat (fixed flange beyond QQS) | 1055 x 82.5 | 0.0 | ±3 | -80.0 | ±3 | -10577 | ±3 | -10561 | ±3 |

Note a: “Left” and “right” are defined as viewed from lead end.

# 7. LBRB – TUNNEL FLOOR INTERFACES

Figure 11 is a bottom view of the cryostat, showing the positions of the internal support posts and the recesses which interface with the support jacks. Along the length of the magnet are located three posts supporting the cold mass within the vacuum vessel. They are positioned at the longitudinal center of the vacuum vessel and 141.5 inches (3594 mm) to either side of center. The support posts attach to CERN vacuum vessel castings which are integral to the vessel at the three locations.

To support the cryostatted magnet, CERN "PMPS" jacks will be used between the floor and the bottom surface of the two outboard vacuum vessel castings. The castings (and the CERN-supplied vacuum port covers) are designed with recesses into which BNL will fit GE-45-SX spherical washers to mate with the jacks. Two jacks will be used at one end of the magnet and one jack at the other. The single jack is located below the magnet midpoint and interfaces with the recess and washer in the CERN supplied port cover. The jacking points are located coincident with the longitudinal center positions of the posts.

The central cold mass support post is partially reacted by the beam stiffness of the vacuum vessel but is shimmed differently from the end posts to eliminate a mid-point sag of the cold mass inside. The midpoint jack support to the tunnel floor at this location can be used to bring the cold mass to a straight, level condition during tunnel installation if further adjustment is necessary.

The outboard floor jacks are capable of resisting axial loads resulting from unbalanced bellows forces due primarily to the vacuum load. Therefore, these forces are transmitted to the tunnel floor through the jacks rather than reacted to adjacent magnet elements.

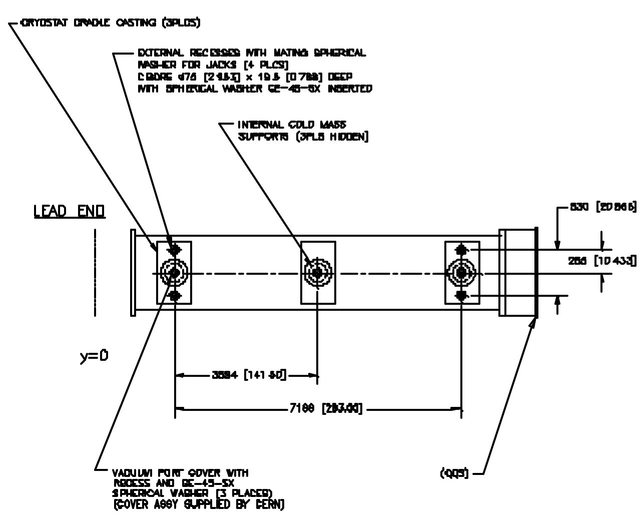



***Figure 11*** ***Jack Locations on the bottom of the LBRB cryostat. Dimensions are given in mm [inches].***

# 8. LBRB – ALIGNMENT SYSTEM INTERFACES

The location of the magnetic field center of the cold mass within the vacuum vessel is known by taking measurements of the cold mass fiducials on the shell and on the end volumes during fabrication and transferring these data to cryostat fiducial locations at the Taylor-Hobson (T-H) spheres in accordance with the CERN preferred method of surveying. The cold mass position relative to the T-H spheres will be measured at BNL. The documentation package shipped with each magnet will include the survey information taken during manufacture. The cold mass position can be checked after shipment to CERN by viewing the end volume and T-H fiducials and comparing the measurements with the data supplied by BNL.

The nominal locations of the Taylor-Hobson spheres with respect to the magnetic axis of the dipole magnet are given in Figure 12.

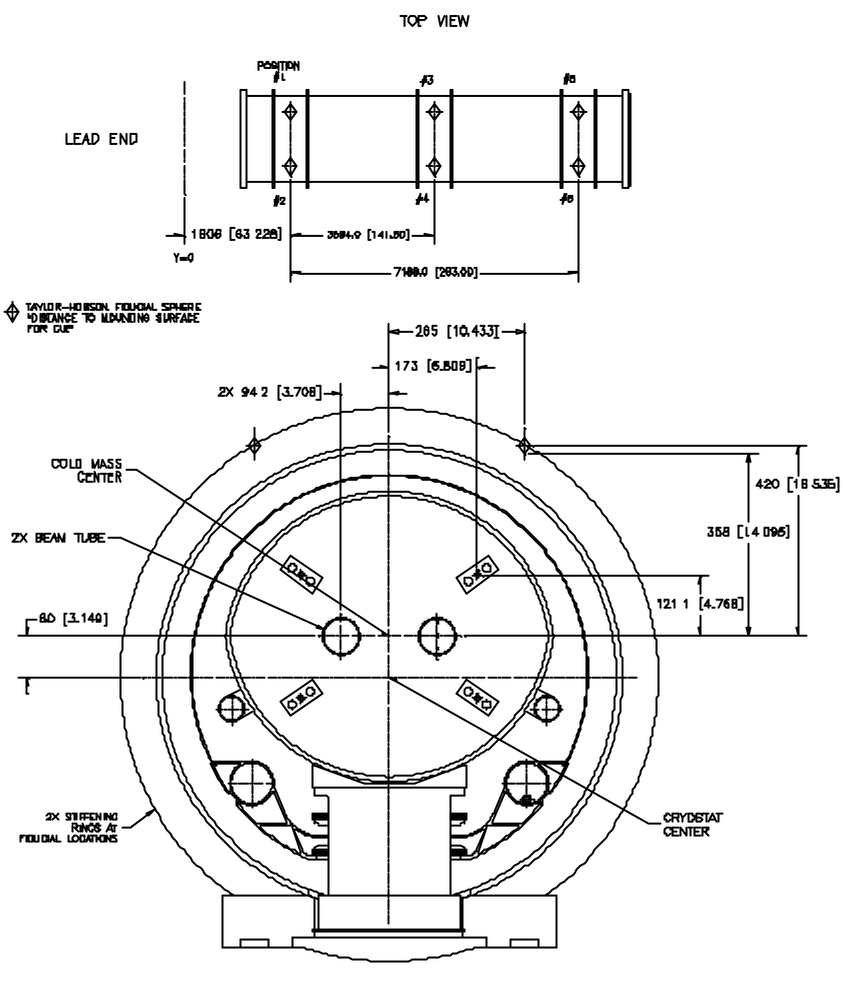



***Figure 12 Fiducial locations on the LBRB cryostat. Dimensions are given in mm [inches].***

# 9. LIST OF DRAWINGS

| | LHC Drawing No. | BNL Drawing No. | Title |
|---|---|---|---|
| [a] | To be assigned | TBD | Magnet Assembly, Tested |
| [b] | To be assigned | TBD | Magnet Assembly, Cryostatted |
| [c] | LHCLBRCA0001 | 14060010-1 | Assembly, D2/D4 Vacuum Vessel |
| | LHCLBRCA0002 | 14060010-2 | Assembly, D2/D4 Vacuum Vessel |
| [d] | To be assigned | TBD | Assembly, Cold Mass |
| [e] | To be assigned | TBD | Assembly, Electro-Mechanical |
| [f] | To be assigned | 14060174 | Flange, m/c Pipe |
| [g] | To be assigned | TBD | IFS Flange |

# 10. REFERENCES

[1] Design Report for the Interaction Region Dipoles and RF Region Dipoles, Brookhaven National Laboratory, January 18, 2000.

[2] “Superconducting Beam Separation Dipoles: D1 (MBX), D2 (MBRC), D3 (MBRS), D4a (MBRA), D4b (MBRB),” LHC Functional Specification, LHC-MBR-ES-0001.00.

[3] “Configurations of BNL-built LHC Dipole Magnets,” Brookhaven National Laboratory, Magnet Note 586, December 7, 1999.

[4] BNL Magnet Division Specification, “LHC Dipole Magnet Beam Tube Material,” LHC-MAG-M-1010, http://magnets.rhic.bnl.gov/maps/documents\LHC-MAG-M-1010.pdf.

[5] “Design Standards – Mechanical Engineering and Installations,” LHC Quality Assurance Standard, LHC-PM-QA-402.00 rev 1.1, 15 November 1999.

[6] “Arc Cryomagnet Extremities,” LHC-LI-ES-0001, rev 2.0, 20 August 1999.

[7] “Beam Separation Dipole D4 Cooling,” LHC Cooling Specification, LHC-MBR-ES-0006.00.

[8] “LHC Magnet Polarities,” LHC-DC-ES-0001, rev 1.1, 19 June 1999.

[9] Balle, C., “Mounting of Industrial Type Cryogenic Thermometers,” version 2.0, CERN, 19 Feb 1999.